FloodSAFE's Flood Emergency Response Support

Guidance for Developing Levee Breach Flood Inundation Mapping

June 13, 2014

1. Purpose

The purpose of this document is to provide guidance and outline the process for preparing flood inundation mapping resulting from pre-selected levee breaches within the Central Valley. The flood inundation mapping will support the Department of Water Resources' (DWR's) Flood Emergency Response program.

2. Background

To aid flood emergency response decision making during flood events in the Central Valley, DWR is developing a system to provide real-time access to flood inundation maps from potential levee breaches within the Central Valley.

The concept is to conduct a series of individual levee breach scenarios at pre-selected locations using the hydraulic models developed under the Central Valley Floodplain Evaluation and Delineation (CVFED) and the Central Valley Hydrology Study (CVHS) programs. The flood inundation maps resulting from these pre-run analyses would be stored and indexed in a digital atlas (i.e., an Oracle database) and retrieved in real time as-needed through DWR's Flood Emergency Response Information Exchange (FERIX) web-application system.

3. Levee Breach Locations

The pre-selected levee breach locations are summarized in Tables 1, 2, and 3. They are also depicted on the attached Levee Breach Location Maps and supporting table. These locations were determined through discussions and recommendations from flood forecasters from DWR and the National Weather Service, as well as DWR's Flood System Repair Project team and CVFED team members.

Table 1. Levee Breach Locations – Regional Distribution

Region				Total
Upper Sacramento	Lower Sacramento	Lower San Joaquin	Upper San Joaquin	
8	22	16	9	55

Table 2. Levee Breach Locations - Sources

Agency / Program / Firm	***Contact***	***No. of Recommended Locations***	
DWR Flood System Repair Project (FSRP)	Dustin Jones, John Johannis and Ran Singh	21	Critical levee repair sites
National Weather Service California-Nevada River Forecast Center (NWS-CNRFC))	Cindy Matthews	15	Urban area - Phase 1
		8	Urban area – future
Atkins	Selena Forman and Ann Bechtel	7	Misc. urban areas (Chico, Woodland, Davis, Stockton)
David Ford Consulting Engineers	Tom Molls and Sarah Rahimi	3	For demonstration purposes
DWR		1	

Total - 55 locations

Table 3. Levee Breach Locations – Phasing of Work for Mapping

Phase	***Location (by unique ID)***	***Total***	***Start***	***Complete***
1	SAC-1, SAC-2, SAC-3, SAC-4, SAC-6, SAC-7, SAC-9, SUB-1	8 (SAC)	June 13	June 27
2	FEA-1, FEA-2, FEA-3, FEA-4, YUB, BEA-2, BEA-1, SUB-2, SUB-3, NAT-1, SJR-2, CWC-2, CWC-3, ESB-2, SJR2	15 (10 SAC and 5 SJR)	June 20	July 7
3	AME-1, AME-2, AME-3, SAC-10, SAC-5, SAC-8, SUB-4, NAT-2, SJR-1, ESB-1, CWC-1, FRR, SJR3-2, SJR3-1	14 (8 SAC and 6 SJR)	July 10	July 25
4	SJR-6, SJR-8, ODR, SJR-7, SJR-5, SJR-4, SJR-3, SDC, NSL, CSR, BRC-2, BRC-1, BRC-3, BRC-4, CAC, SYC-2, SYC-1, BUC1	18 (14 SJR and 4 SAC)	August 1	August 15

4. Levee Breach Hydrographs

DWR is developing breach hydrographs for the pre-selected locations and will provide them to the mapping contractors as they are completed based on the phasing indicated in Table 3. At each location, individual breach hydrographs corresponding to three in-

channel stages and two simulated historical event patterns (i.e., 1997 and 1986) are being developed. Therefore, at each levee breach location, six breach hydrographs are being developed for a total of 330 hydrographs (i.e., 55 locations x 3 stages x 2 events).

Specifying the In-Channel Stages for the Levee Breach Locations

At each location, levee breach hydrographs are being developed for three in-channel stages: minimum; maximum; and intermediate. The minimum stage is at least three feet above the land-side levee toe elevation. The maximum stage is the lower of the top-of-levee elevation and the approximate 500-year stage.

If available historical or forecast stage information (i.e., peak stage of record, flood stage, or danger stage), then this stage information is being used to inform the selection of the three stages. If frequency information is not readily available (i.e., for levee breach locations lying outside of the CVHS domain), then the top-of-levee elevation is being used. Otherwise, the maximum and minimum stages indicated above, and one intermediate stage (e.g., three feet below the top-of-levee elevation) will be used.

The top-of-levee stage represents an extremely rare event at some locations. The 500-year stage represents an upper bound and is being estimated using information from the nearest CVHS frequency curve.

Levee Breach Parameters

The levee breach parameters are being based on the CVFED guidelines as follows:

- Final bottom width ≈ 50 x levee height
- Final bottom elevation ≈ landside toe elevation
- Side slopes = 0
- Breach weir coefficient = 2.0
- Full formation time = 6 hours
- Failure mode = Overtopping
- Trigger failure at = Water Surface Elevation
- Starting Water Surface = 0.1-foot below peak stage

Developing the Levee Breach Hydrographs

For locations lying inside the domain of the CVHS/CVFPP models, the breach hydrographs are being developed using a two step process utilizing the HEC-RAS system model developed by the CVHS program and modified by the Central Valley Flood Protection Plan (CVFPP) program.

Step 1 - The HEC-RAS model is being executed with levee overtopping only (no levee breaches) for various scalings of the 1997 and 1986 historical events. This first step associates the peak stage at each breach location with the event scaling.

Step 2 - The HEC-RAS model is being executed with a levee breach defined at each breach location. Each HEC-RAS model run will only have one of the levee breaches activated at a time. Using the information from Step 1, the HEC-RAS model will be set up to initiate the levee breach 0.1 feet below the peak stages and executed using the scaled flood event that most closely produces the desired peak stage. Therefore, all levee breaches will be initiated at the peak stage thus producing consistent levee breach hydrographs.

For locations lying outside the domain of the CVHS/CVFPP models, the HEC-RAS models developed by the CVFED program are being used. Additional hydrologic analysis to determine the HEC-RAS inflow boundary conditions for the 1997 and 1986 historical events are required. The levee breach hydrographs are being developed for the full CVHS event time window.

The breach hydrographs provided to the mapping contractors account only for positive breach flows (flows leaving the channel). Negative breach flows (flows re-entering the channel) are not accounted for.

Several locations may require modifications to the procedure outlined above. If so, the modifications will be submitted to DWR for review and approval prior to developing the hydrographs and release to the mapping contractors.

5. Flood Inundation Maps

The mapping contractors will produce the flood inundation maps. DWR will provide the mapping models (FLO-2D or TUFLOW) and breach hydrographs to the mapping contractors. The mapping contractors will execute the mapping models to compute the area of inundation, and develop the resulting flood inundation maps. The flood inundation maps will include flooding extents and depths. The overall process is depicted in the Figure 1.

At each levee breach location, the models are to be executed using six different breach input hydrographs resulting in six different inundation areas. Each inundation area (i.e., flooding extents and depths) are to be mapped using GIS and a specified template provided by DWR. Therefore, a total of 330 separate FLO-2D model runs are required thus producing 330 individual flood inundation maps.

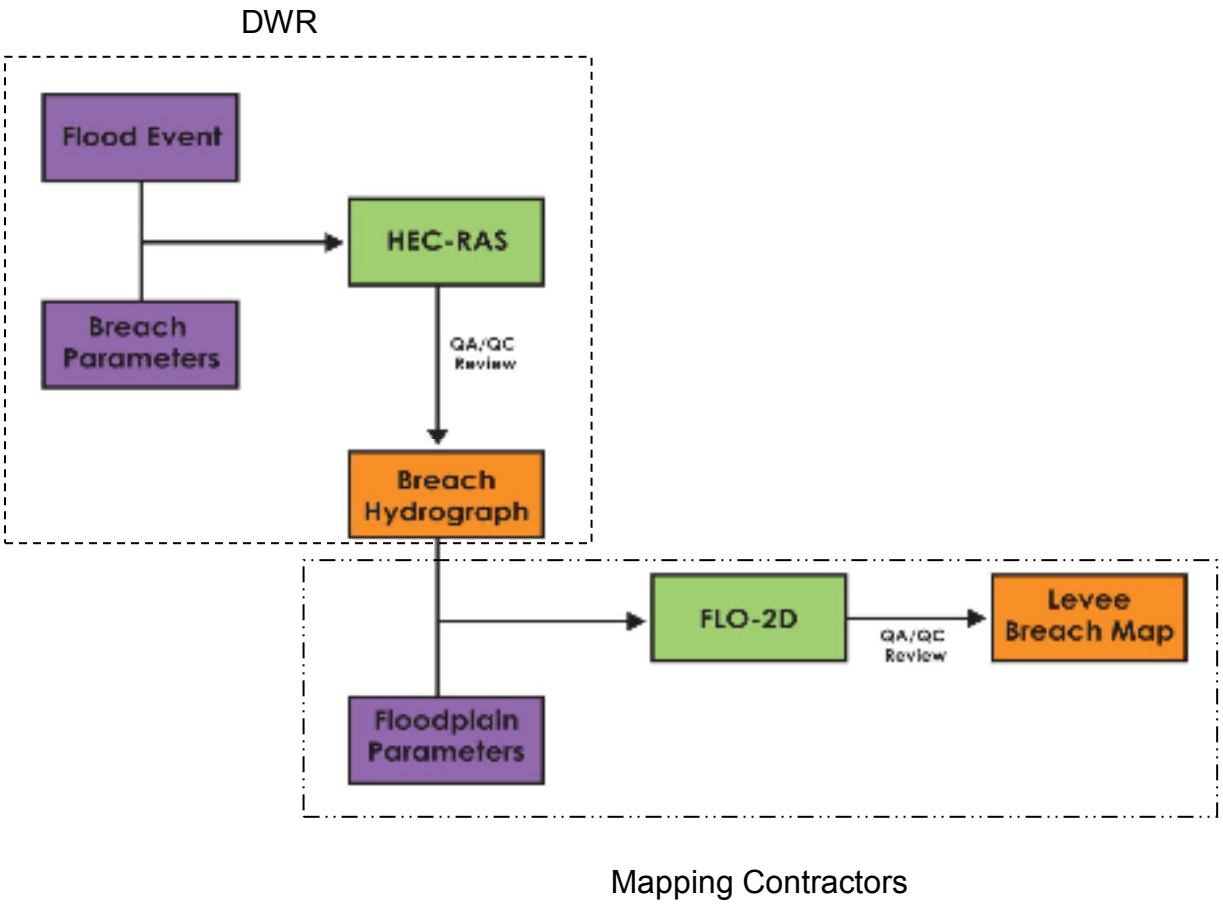


Figure 1. Flood Inundation Mapping Process

Mapping Model Layout and Approach

Prior to executing the mapping models, the mapping contractors are required to meet with DWR to review and gain acceptance of the model layout and approach.

A model layout map(s) will be developed showing the levee breach locations and associated model domains. At a minimum, the GIS map should include the following features:

- Levee breach location
- FLO-2D (or TUFLOW) model domain
- Levees and embankments (and openings) in the models
- 1-dimensional channels embedded in the models

The mapping contractors are also required to develop a brief technical memorandum describing the proposed model layout for each levee breach location. At a minimum, for each breach location, the memorandum will describe: (1) which models will be used to

develop the mapping products and (2) any potential challenges associated with developing the mapping products (and, if appropriate, a recommended solution).

Mapping Model Execution

The FLO-2D (or TUFLOW) models are to be executed using the following parameters:

- Use the existing CVFED parameters and hydraulic structures (e.g., Manning's *n* distribution, Area Reduction Factors (ARFs) and Width Reduction Factors (WRFs), embankments, culverts)
- Embankments are to be modeled as overtopping without failure
- The Courant stability coefficient is to be set to 0.6
- The model simulation time is to be sufficient to establish peak depths throughout the inundated area; the maximum required model simulation time is estimated to be 20 days
- Time dependent data is to be created at an appropriate time interval; the maximum time increment is four hours

Each model will be executed utilizing a single levee breach hydrograph input into the grid cell (or cells) adjacent to the levee breach location. The hydrograph may span several grid cells but the total width of the inflow cells should not be significantly larger than the final breach width.

Mapping Model Output

For each model run, the following output products are to be created and delivered to DWR:

- All ASCII input and output files (including time-dependent information, e.g. the FLO-2D TIMEDEP.OUT file)
- GIS shapefiles of grid cell ground elevation, maximum floodplain depth and water surface elevation, maximum channel depth, maximum combined channel and floodplain depth, maximum floodplain velocity, maximum channel velocity, levee freeboard deficiency, time for 1-foot, 2-foot, and maximum depth, and time dependent flow depth and velocity
- A summary table listing the following information: total breach inflow volume, peak breach inflow, total number of FLO-2D grid cells, number of inundated (wet) grid cells, inundated floodplain area (excluding 1-dimensional channel cells), and average floodplain depth (excluding 1-dimensional channel cells).

The output GIS shapefiles are to be stored in a directory separate from the ASCII input and output files. Another separate directory (within the output GIS shapefile directory) is to be created to store the time dependent output GIS shapefiles.

Some locations may require modifications to the procedure outlined above. If so, this information will be submitted to DWR for review and approval.

Inundation Mapping Products

The inundation mapping products will be GIS-based using a map template provided by DWR. The template resembles that used for the Task Order No. 32 except these maps are to be single, stand alone maps and not indexed map books. The final deliverable to DWR will be pdfs of the maps and the supporting GIS files.

Final DWR Approval

The mapping contractors are required to provide the mapping model output and inundation mapping products described above (pdfs and GIS) and a brief technical memorandum describing the development of the levee breach inundation mapping products to DWR for approval.

DWR-Provided Items

DWR will provide to following to the mapping contractors:

- The corresponding GIS files supporting the Levee Breach Location Maps included in the attachment
- A copy of the HEC-RAS model used to develop the levee breach hydrographs for each levee breach location
- A summary spreadsheet documenting the following for each levee breach location:
  - cross section figure with three proposed stages
  - lateral weir figure
  - levee breach parameters
  - levee breach hydrographs
  - trigger water surface elevation
  - associated event scaling
  - peak levee breach flow
  - total levee breach volume
- HEC-DSS file containing all the levee breach hydrographs
- A brief technical memorandum describing the development of the levee breach hydrographs.
- DWR-approved FLO-2D (or TUFLOW) model (Library of Models version)
- Map template

6. Quality Management

Quality management will be comprised of quality control and quality assurance. Quality control will be the responsibility of the entity producing and delivering the products. Quality assurance will be accomplished by DWR.

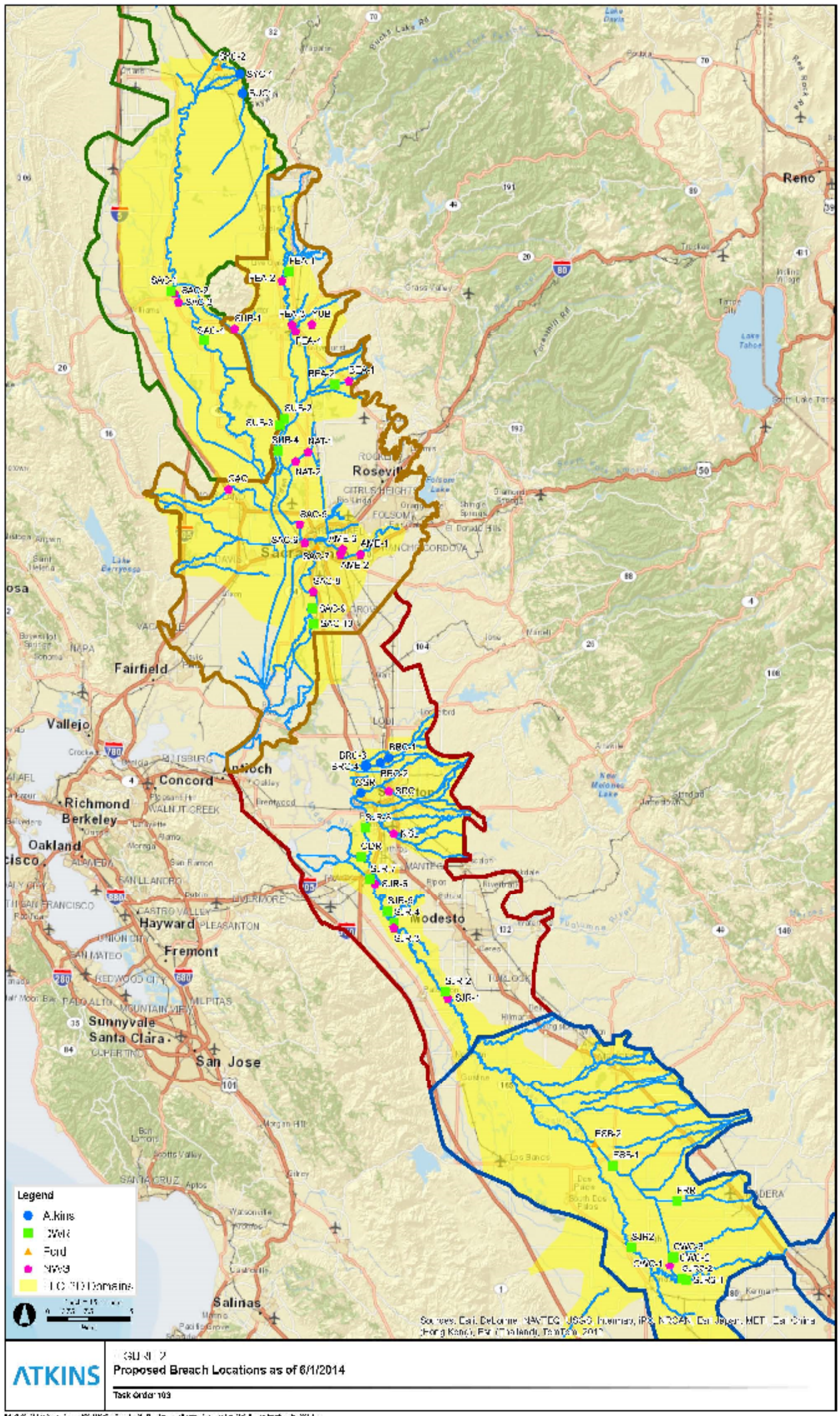
The levee breach hydrographs provided by DWR will undergo a thorough internal quality control and quality assurance review prior to distribution to the mapping contractors. The levee breach hydrographs will be reviewed for the following:

- Check that levee breach hydrographs are provided for all specified breach locations
- Check that the levee breach is modeled at the correct location
- Check that the appropriate water surface elevation triggers are used
- Check that the other levee breach parameters adhere to the guidelines except where differences are approved by DWR
- Check the hydrographs for reasonableness
- Check that GIS files match the model input parameters

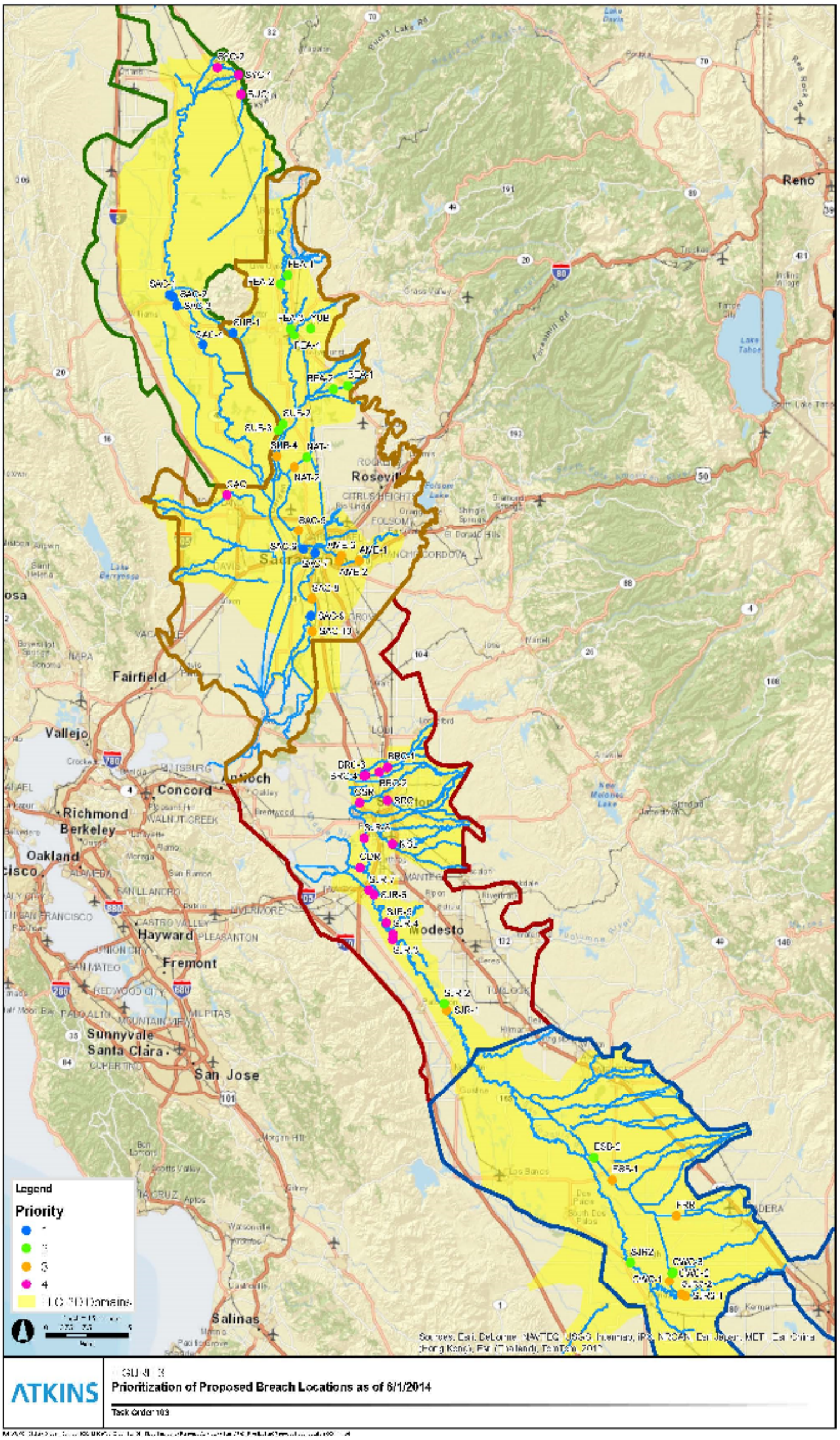
The mapping contractors will set up and execute the mapping models and produce the flood inundation mapping products. The mapping products will be reviewed by DWR for the following:

- Check that the correct model build is used
- Check that the input levee breach hydrograph matches that provided by DWR
- Check that the breach hydrograph is input at the correct location over a reasonable number of model grid cells
- Check that the deliverable matches the model run (i.e., re-run model and confirm the results)
- Check the resulting inundation area and depths for reasonableness
- Check that that all of the output products are delivered and in the correct format

ATTACHMENTS



Attachment 1a - Levee Breach Locations


Reno
Roseville
Fairfield
Vallejo
Concord
Antioch
Richmond
Berkeley
Oakland
Hayward
Fremont
Sunnyvale
Santa Clara
San Jose
Modesto
Salinas
Legend
Priority
1
2
3
4
ATKINS
Prioritization of Proposed Breach Locations as of 6/1/2014
Task Order 109

Count	UniqueID	Phase	Lat	Long	River	Associated	Bank	AEC	Red_Ht	FLO2D_DM	HECRAS	HECRAS_XS	LabelType
1	SAC-6	1	38.5967	-121.5450	Sacramento River	I Street	RB	WR	5.40	West Sacramento/Clarksburg	SAC CVFPP	Sacramento River NCC to NEMDC XS 62.7519	NWS
2	SAC-8	3	38.4754	-121.5150	Sacramento River	I Street	LB	WR	10.12	American River South	SCA CVFPP	Sacramento River DS American XS 48.0025	NWS
3	SAC-5	3	38.6432	-121.5630	Sacramento River	I Street	LB	WR	6.50	Natomas	SAC CVFPP	Sacramento River NCC to NEMDC XS 66.2529	NWS
4	AME-1	3	38.5702	-121.3570	American River	H Street	LB	WR	0.00	American River South	SAC CVFPP	American River Reach 1 XS 10.5	NWS
5	AME-3	3	38.5818	-121.4180	American River	H Street	RB	WR	0.00	American River North	SAC CVFPP	American River Reach 1 XS 5.58333	NWS
6	FEA-2	2	39.2496	-121.6370	Feather River	Yuba City	RB	WR	9.20	Feather River West	SAC CVFPP	Feather River Honcut to Jack XS 38.71	NWS
7	FEA-4	2	39.1237	-121.5880	Feather River	Yuba City	LB	WR	0.00	Yuba River South	SAC CVFPP	Feather River Yuba R - Bear R XS 26.75	NWS
8	CAC	4	38.7281	-121.8060	Cache Creek	Yolo	RB	WR	1.00	Cache Creek TUFLOW. Willow Slough Bypass?	Lower Sacramento	CAC R1 XS 12.078	NWS
9	SJR-1	3	37.4695	-121.0480	San Joaquin River	Newman	LB	HDR	6.10	LSJR	SJ CVFPP	SJR20 REACH20 XS 99.69	NWS
10	CWC-1	3	36.8069	-120.3090	Chowchilla Bypass - Firebaugh	N/A Use Bypass Flows	LB	RBF	0.00	SPFC	SJ CVFPP	UBYP5 REACH5 XS 29.56	NWS
11	YUB	2	39.1430	-121.5330	Yuba River	Marysville	LB	WR	0.00	Yuba River South	SAC CVFPP	Yuba OB mid XS 2.28	NWS
12	SJR-6	4	37.7524	-121.2940	San Joaquin River	Mossdale	RB	HDR	1.62	LSJR	SJ CVFPP	SJR26 REACH26 XS 59.76	NWS
13	SAC-2	1	39.2136	-122.0000	Sacramento River	Colusa Bridge	RB	CH2	2.70	Lower Sacrmento	SAC CVFPP	Sacramento Redding XS 143.239	NWS
14	NAT-1	2	38.8239	-121.5390	Natomas Cross Canal		LB	WR	0.00	Natomas	SAC CVFPP	Cross Canal Main XS 4.82	NWS
15	SAC-3	1	39.1915	-121.9860	Sacramento River	Colusa Bridge	RB	CH2	13.40	Upper Sacramento	SAC CVFPP	Sacramento Redding XS 141	NWS
16	SAC-1	1	39.2180	-122.0120	Sacramento River	Right bank north of Colusa	RB	CH2	2.70	Upper Sacramento	SAC CVFPP	Sacramento Redding XS144	DWR
17	SAC-4	1	39.0950	-121.8960	Sacramento River	Right bank north of Grimes	RB	CH2	6.90	Upper Sacramento	SAC CVFPP	Sacramento Redding XS 127.25	DWR
18	FEA-1	2	39.2723	-121.6130	Feather River RD 10	RD 10	LB	WR	8.80	Honcut South/Yuba River North	SAC CVFPP	Feather River Honcut to Jack XS 42.19	DWR
19	BEA-2	2	38.9918	-121.4521	Bear River	Near Wheatland right bank	RB	WR	8.25	Bear River/Coon Creek	SAC CVFPP	Bear River Upper XS 9	DWR
20	SUB-2	2	38.9048	-121.6202	Sutter Bypass		LB	WR	12.30	Feather River West	SAC CVFPP	Sutter Bypass Tisdale-YoloBP XS 67.38	DWR
21	SUB-3	2	38.8886	-121.6359	Sutter Bypass		RB	CH2	11.75	Lower Sacramento	SAC CVFPP	Sutter Bypass Tisdale-YoloBP XS 66.45	DWR
22	SUB-4	3	38.8254	-121.6391	Sutter Bypass		LB	WR	12.45	Bear River/Coon Creek	SAC CVFPP	Sutter Bypass Tisdale-YoloBP XS 61.82	DWR
23	SAC-9	1	38.4340	-121.5175	Sacramento River		LB	WR	9.70	American River South	SAC CVFPP	Sacramento River DS American XS 44.4976	DWR
24	SAC-10	3	38.3966	-121.5119	Sacramento River		LB	WR	9.70	American River South	SAC CVFPP	Sacramento River DS American XS 40.7534	DWR
25	SJR-8	4	37.8898	-121.3293	San Joaquin River		LB	HDR	8.10	LSJR plus RAS Storage Areas	SJ CVFPP	SJR30 REACH30 XS 45.31	DWR
26	ODR	4	37.8182	-121.3419	Old River	North side	RB	HDR	9.74	LSJR	SJ CVFPP	OLD1 REACH31 XS 33.651	DWR
27	SJR-7	4	37.7634	-121.3110	San Joaquin River		LB	HDR	8.96	LSJR Plus RAS Storage Areas	SJ CVFPP	SJR26 REACH26 XS 57.81	DWR
28	SJR-5	4	37.6820	-121.2520	San Joaquin River		RB	HDR	5.79	LSJR	SJ CVFPP	SJR26 REACH26 XS 69.02	DWR
29	SJR-4	4	37.6538	-121.2291	San Joaquin River		RB	HDR	8.20	LSJR	SJ CVFPP	SJR24 REACH24 XS 73.83	DWR
30	SJR-2	2	37.4850	-121.0577	San Joaquin River		RB	HDR	6.20	LSJR	SJ CVFPP	SJR20 REACH20 XS 98.4	DWR
31	FRR	3	36.9683	-120.2873	Fresno River		RB	RBF	4.40	SPFC	SJ CVFPP	FRERIV REACH6 XS 5.4943	DWR
32	CWC-3	2	36.8298	-120.2978	Eastside Bypass		RB	RBF	7.30	SPFC	SJ CVFPP	UBYP5 REACH5 XS 27.57	DWR
33	CWC-2	2	36.8281	-120.3001	Eastside Bypass		LB	RBF	7.10	SPFC	SJ CVFPP	UBYP5 REACH5 XS 27.57	DWR
34	SJR3-2	3	36.7731	-120.2693	San Joaquin River		RB	RBF	4.60	SPFC	SJ CVFPP	SJR1 REACH1 XS 215.62	DWR
35	SJR2	2	36.8534	-120.4363	San Joaquin River		RB	RBF	9.30	SPFC	SJ CVFPP	SJR3 REACH3 XS 193.74	DWR
36	SJR3-1	3	36.7695	-120.2553	San Joaquin River		LB	RBF	4.40	SPFC	SJ CVFPP	SJR1 REACH1 XS 216.51	DWR
37	ESB-1	3	0.0000	0.0000	Eastside Bypass	Critical subsidence point	RB	RBF	6.60	SPFC	SJ CVFPP	UBYP11 REACH11 XS 6.7028	DWR
38	ESB-2	2	0.0000	0.0000	Eastside Bypass	Demo Breach Location	LB	RBF	5.60	SPFC	SJ CVFPP	UBYP11 REACH11 XS 1.6812	Ford
39	SAC-7	1	0.0000	0.0000	Sac River nr West Sac	Demo Breach Location		WR	0.00		SAC CVFPP	Sacramento River DS American XS 59.7519	Ford
40	SYC-2	4	0.0000	0.0000	Sycamore Creek	Demo Breach Location	LB	CH2	4.00	Chico	Upper Sacramento (Chico)	SYC Reach2 XS 1.198	Ford
41	AME-2	3	0.0000	0.0000	American River	H Street	LB	WR	0.00	American River North	SAC CVFPP	American River Reach 1 XS 6.5	NWS
42	SDC	4	0.0000	0.0000	Stockton Diverting Canal	Waterloo Road	LB	HDR	2.00	SJFCA	SJAFCA	MNS 2 XS 9145.2	NWS
43	BEA-1	2	0.0000	0.0000	Bear River	Wheatland/Above 65/gage	RB	WR	0.00	Bear River/Dry Creek	SAC CVFPP	Bear River Upper XS 11.66	NWS
44	FEA-3	2	0.0000	0.0000	Feather River	Marysville	LB	WR	18.30	Honcut Creek South/Yuba River North	SAC CVFPP	Feather River Jack SI - Yuba R XS 28	NWS
45	SJR-3	4	0.0000	0.0000	San Joaquin River		LB	HDR	7.41	LSJR	SJ CVFPP	SJR24 REACH24 XS 74.87	NWS
46	SUB-1	1	0.0000	0.0000	Sutter Bypass			WR	4.05	Feather River West	SAC CVFPP	Sutter Bypass ButteSI-Wads XS 85.81	NWS
47	NAT-2	3	0.0000	0.0000	Natomas Cross Canal		RB	WR	10.80	Bear River/Coon Creek	SAC CVFPP	Cross Canal Main XS 1.99	NWS
48	NSL	4	0.0000	0.0000	Little John Creek		?	HDR	1.80	SJFCA and/or LSJR depending on which bank	SJAFCA	NSL 1 XS 580.864	NWS
49	CSR	4	0.0000	0.0000	Calaveras River		RB	HDR	5.00	SJFCA	SJAFCA	CSR 1 XS 8401.35	Atkins
50	BRC-2	4	0.0000	0.0000	Bear Creek		LB	HDR	6.00	SJFCA	SJAFCA	BRC 2 XS 31110.9	Atkins
51	BRC-1	4	0.0000	0.0000	Bear Creek		LB	HDR	6.00	SJFCA	SJAFCA	BRC 2 XS 42195.4	Atkins
52	BRC-3	4	0.0000	0.0000	Bear Creek		RB	HDR	4.00	SJFCA	SJAFCA	BRC 2 XS 17492.8	Atkins
53	BRC-4	4	0.0000	0.0000	Bear Creek		LB	HDR	1.00	SJFCA	SJAFCA	BRC 2 XS 15762.7	Atkins
54	SYC-1	4	0.0000	0.0000	Sycamore Creek		LB	CH2	4.00	Chico	Upper Sacramento (Chico)	SYC Reach1 XS 5.849	Atkins
55	BUC1	4	0.0000	0.0000	Butte Creek		LB	CH2	7.70	Chico	Upper Sacramento	BUC1 Subreach1 XS5477.03	Atkins